

A CRITIQUE OF RELATIVITY AND LOCALIZATION

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Abstract—A new philosophical model makes particles and information at single points derivative. Space-time grids are not events but only ideal comparisons made by observers. Therefore the identity of space-time points and also of single particles is inherently a speculative assumption. The conservation of units can be derived and is not a foundation for events. An interaction is an actual change and can determine changed particles and a changed space-time grid from itself, both forward and backward in time. In contrast, relativity theory still retains the classical unit model in which information is localized at single points, merely positing more than one observer. One implication of the new model is that quantomechanical solutions need not be limited by the requirements of relativity as is currently done. The model correctly predicts where difficulties should be found, and relates and explains many puzzles which are otherwise separated and inexplicable.

SECTION I

From one philosophical analysis [1] it follows that spatial location, point in time, and the identity of a single particle should be definable only *retroactively*, from processes of change. We predict that physics must eventually give up pointwise localization in space and time and single, noninteracting particle states. There will always be two or more particles, and their definitions, as well as those of places and times, will be definable only backwards, from interaction.

Einstein's [2] special theory of relativity already denies the definability of a space or time point without reference to the space and time of some observer. Absolute space and time points do not exist uniquely. The transformation equations named for Lorentz are a set of rules to transform observations made relative to one observer into those made relative to another observer. But in these equations all parameters in each observer's system are still formulated along classical lines, namely as attached to independent single points of space and time. Thus, for each observer system, the concepts of space, time, and single particle are still quite as absolute as those of Newton.

If it were true, as we will try to show, that single space and time points and a single particle are in some way inadmissible, a basic change would be involved also in the conception of certain phenomena. In relativity, a special place is assigned to the class of phenomena which are used to signal from one observer to another (light is the usual example). The properties of these signal phenomena are constrained by the role they are made to play in the theory,

a role dictated by what remains of absolute space and time in the theory. These properties are not of empirical origin, but are forced on these phenomena in order to make possible the signaling between two classical observers.

It may well be, therefore, that if we decide to give up the vestige of absolute space and time, we should also find our description of these phenomena closer to the *minimal empirical description*. Their role as possible signals in relativity introduces *speculative* features in a theory still using absolute space and time, features which we will attempt to isolate and remove.

By *speculative* we mean those features of theoretical descriptions which cannot be traced to decisions based on empirical findings. Such features are in principle open to being changed. We shall find in our inquiry that it is precisely those features which also seem to be at the heart of present difficulties in the theoretical description of recently explored phenomena.

We began with this lead, that features due to the role of reconciling absolute space and time systems are speculative and open to change. We found that by separating out just these features we were also separating out just those unjustified assumptions most responsible for present difficulties in physics.

Relativity, it is known, creates a host of dilemmas and contradictions when it is forcibly imposed upon the quantum theories of modern physics. We will inquire into the possibility that these contradictions vanish when absolute space and time are finally excised from our theories, and along with them what relativity imposes upon phenomena in order to reconcile systems of absolute space and time. The requirements of reconciling two such systems has, in relativity, been put ahead of empirical considerations.

Let us now examine in detail what seems to be a basic philosophical inconsistency of relativity, and then pursue its effects in recent anomalies in more detail.

The “signal properties of light” are due to its carrying of “information.” The classical notion of “information” contains a contradiction: information is purely about one point in space and time. Information is supposedly purely about there and then, and yet it would not be information if it were not had by someone who is somewhere else. “Information” is supposedly both *had somewhere*, and yet also supposedly *purely about one place somewhere else*. Relativity keeps this *point character of information*.

Light is made to embody the difficulty of two or more space–time location systems (observer coordinate frames). That each space–time system remains as is, and only their relation via signaling is affected is insured, but leads to the need for a sharp maximum signal speed, c , such that

$$c \oplus v_{\text{REL}} = c$$

for all systems (observers).

In relativity, the parameters are still single point descriptions, e.g., field strengths, $A\mu(x, t)$. Relativity falls short of *reformulating the parameters themselves*, so that they would no longer be about independent single points.

Now, if quantum theory is a body of theory and empirical data whose parametrization always involves more than one point, i.e., interactions, then we would expect relativity to contradict quantum theory exactly in those respects in which relativity requires single point descriptions and in the respects in which it forces certain speculative properties on light (or other $v_{\text{signal}} = c$ phenomena), to enable it to signal between such single points. It follows that whatever results from the *information contradiction* in relativity should be unnecessary and troublesome.

Let us now examine more closely what is involved in space and time points. The labeling of phenomena by space and time must always be the function of someone who compares. A comparer marks off one motion on another. The intervals during which one motion occurs,

as marked off on another motion, say something about their comparison. They say nothing about each motion. Thus, if a given motion's duration is expressed in terms of revolutions of the earth, or divisions thereof, the expression in days or hours says something about the *comparer* who has expressed one motion in terms of parts of the other. Nothing is thereby said about each motion as an empirical phenomenon. Rather, this interval parametrization of motions says something about the comparer's activity, and depends upon the motion used as a standard in relation to the other motion being compared.

Motions so compared are not actually interacting with each other in any way, nor is the observer impinging on either. Thus, time point definition already involves adding something to the description of phenomena, in regard to which the phenomena are in fact neutral.

Similarly, a space location system is the product of an observer who relates different observables to each other in terms of the direction from the observer to them. A motion can then be described in terms of other phenomena which define a space interval.

The interval covered is expressed in terms of other phenomena. These do not interact with the given motion and it is neutral with respect to them. The same interval supposedly exists without the motion.

Thus motions are described in terms of static points derived from intervals between other phenomena with which the given motion is not in interaction.

Motion thereby becomes defined as a "from-to," in terms of static locations, so that instead of motion we have only the empty interval and its static points.

The triumph of Einstein's discussion of simultaneity was that he succeeded in eliminating the ambiguity of intervals by comparers who were not at rest relative to each other, so that we may say that motion finally becomes the comparison of static intervals.

But have we not lost something by all this? How shall we distinguish between an object in motion and one at rest in each successive location? In interval parameters there is no way to formulate the question, but if our hand were on the object we would know which case obtained. But there is, of course, a parameter which expresses this difference: momentum, a dynamic (interactional) rather than kinematic (interval) parameter.

As we saw, space and time location descriptions are artificial in the sense of relating, comparing, putting into interaction of an unreal sort, two phenomena or more which are not actually in interaction. Thus, the space-time descriptions do not distinguish between events actually in interaction with each other and events only being compared. The space-time description neutrally assigns relation to phenomena that are not relating, and conversely, also describes interactions as though they were merely intervals or comparisons.

In quantum theory, on the other hand, the basic concept is that of *interaction*; and, we will argue, it is natural in quantum theories to regard location and time as *derivative* from interaction, and to distinguish actual interaction from mere comparison.

Interaction is essentially a *here-there A-B* concept, labeled always by more than one parameter of each type (or equivalently by relative parameters, such as angles).

Quantum theory does not require the assumptions of an absolute space-time with independent point-locations. More than that, it enables us to describe actual interactions, of which, it would seem, space-time location is a kind of artificial copy. For example, the comparer assigns space interval description to some motion, in terms of the change in angle by which he can locate it. From the start to the end the motion defines for the comparer an angle. But this is no real angle of some interaction descriptive of the motion. Rather, the angle describes the observer's attempt to interact with the motion. Does the observer succeed in actually interacting with it? If not, then nothing empirical is said about a motion by the space location the comparer attempts to foist on it, as an artificial interaction. If yes, then only is the angle of empirical import, but then also the angle describes some change, and cannot be reduced to a mere empty interval of a static comparison system.

If space and time location intervals are viewed as angles of would-be interactions, and not

that interactions go on "in" static space and time interval systems, then *at least* we can argue that the dynamic (interactional) parameters are primary, and the kinematic (location) parameters must be taken out of the way descriptions are fundamentally fashioned. But in conventional theories which are built to accord with relativity (local field theories), the assumptions of kinematics are built into the descriptive parameters. One should therefore expect to find that these are troublesome features.

What is more, it is possible that the Lorentz transformations themselves will become understandable and derivative if we consider space-time intervals as artificial interaction and their actual measurement as an actual interaction.

Currently, the space-time systems (and their transformations) are taken as the most general and overall requirements, within which interactions are made to be placed. We propose reversing this and making actual interaction (and dynamic parameters only) the more general framework within which measurements are one kind. Space-time location parameters of actual interactions would be derived from actual interactions.

Let us look more carefully at this "comparison" nature of time and space which we have been calling artificial.

Time enters our theories at first as a parameter for the comparison of motions. A standard motion is chosen (falling sand, dripping water, the apparent motion of the sun) and all other motions are marked-off upon it, the moments of their commencement and termination. Thus, time *intervals* are introduced; and we end by assuming that all motions may be consistently represented in a single *intercomparing system*. Time interval is thus reducible to length, a difference in position of the system whose motion is our standard (the clock face, height in a cylinder, etc.). Even if the system is not a body in motion (say a light that periodically changes its color through the spectrum), there will always be an analogue of the length, the difference in position (here, the difference in color); and we require only that it be possible to define an equality of differences that is independent of where (or when, or at what color) the motion observed begins and ends. It is furthermore assumed in classical theories, including relativity, that this independence of when during the standard motion an interval is chosen, so far as its length in comparison to intervals beginning at other times is concerned, allows us to imagine that everywhere in the universe, and at all times, the unit interval is defined, provided only that it is defined once and somewhere. This last assumption is far from a trivial one, as was demonstrated by Hermann Weyl early in the century [3]. He showed that the assumptions restricted the freedom of the theory by as many parameters as are required to represent all of electromagnetism. This is because, without the assumption, we are free to redefine the unit interval of distance and of time at every point of *space-time*.

This view of space and time, however, with all the classical assumptions, seems to have reduced all motion to a mere comparison of intervals. The difference is interaction (or possible interaction, as we will see below). Physics recognizes a distinction between kinematic and dynamic statements. Locations at successive times are only so many units of an observer's arbitrary space per so many units of his equally arbitrary time. This description is purely kinematic. On the other hand, what distinguished motion from statics is impulse, change and transfer of *momentum*. Momentum always concerns interaction, transfer of momentum or impulse. It is always at least two momenta which are relevant to an interaction (see Fig. 1). A single momentum may be thought of as partial information about possible interactions with another momentum.

Impulse, or change of momentum, is impossible at a *single* instant of time. From the viewpoint of momentum, or more exactly, change in momentum (interaction) therefore, the interval is clearly more basic than the time-points marking its beginning, end, or any other point between. It is therefore possible to consider time intervals as inherently related to actual interaction (or change in momentum), rather than as the difference between two points in an antecedently given system of artificial interactions between single independent points.

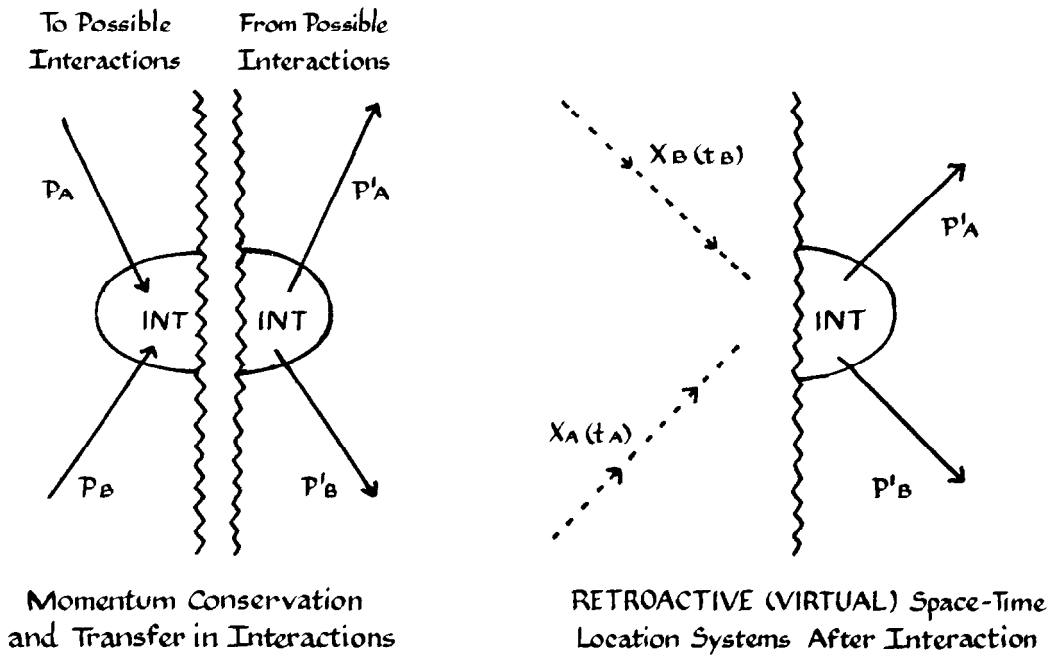


Fig. 1.

It is worth exploiting the concept of momentum as a true interaction concept to see how it can help us avoid the usual space-time (kinematic) ways of thinking.

Let us view the momentum of a body as describing *in part* what we may expect *if* the body were to interact with another whose momentum is also specified. Momenta were invented only to be used in conjunction with other momenta; it is *sums* of momenta which are conserved, and it is the *relative* momentum transferred during an interaction which is an essential parameter describing an interaction. Thus, "momentum of a single particle" can be viewed as stating many possible specified interactions with a particle of another momentum.

In the same way, the momentum of a particle also tells the possible interactions from which it might have emerged with its present momentum. Of course, any of these would have *changed* its velocity and direction, so that it now appears to be "coming from" a place at which it never was! Its momentum, therefore, does not really tell us where and when it was, but only about interactions that could have made it now seem to be coming out of the given direction with the given velocity.

Any actual interaction thus generates for the particle a new set of possible interactions from which it could have come and could be entering further into. It thus generates a system of places and times at which it seems to have been and seems going to be. Any further actual interaction will change this system into another one.

But now, which is more basic? Will, as the above shows, the space and time point systems be derivative from an actual interaction? Or must we place actual interactions (and the systems before and after it) into one consistent overarching system of space and time points? It should be clear that it cannot be the latter because, as we just showed, the space and time system is not literal for the particle but is only an expression of the interaction it comes from. Rather than saying the interaction it comes from, a system of spaces and times is laid out behind it, from which it does not actually come.

A point of view somewhat like ours has been developed recently from other arguments by Julian Schwinger in his sourcery theory [4].

There is little reason to want actual interaction and its generating of space and time systems still to go on in a space and time point system. Rather, actual interaction should have precedence and can redefine space and time points. (The actual interaction could be one of measurement.)

Relativity can be retained to deal with the relations added onto phenomena by observers, without requiring that such considerations be the widest system within which all other descriptions must conform. Instead, we can make the Lorentz equations a limiting case of more general relations defined by interactions.

We would predict that conventional theories will break down if they try to satisfy the Lorentz equations *during* an interaction as though the interaction occurred *in* space-time in antecedent locations corrected by the equations. In our view, interaction is not localized (tied to single points of space and time), but defines *slots* or *channels* characteristic of the interaction, which are then spoken of as particles.

For Newton, the connection between kinematic parameters and dynamics was accomplished by introducing the idea of mass. It was mass which made bodies more than mere time and space points in the comparing system. In the classical system, a particle was regarded as a single moving mass point; that is to say, it was regarded kinematically in terms of the absolute space-time, and the notion of mass was included to allow for the dynamics. Modern theories are stated directly in terms of momentum. To do so fully would alter the notion of "particle." We would retain "mass," or the dynamical aspects it was intended to include, of course, but would eliminate the "point" aspect of particle or mass point. To define particle independently of motion through space-time (the artificial interactions of the comparer), we redefine it. We mean by particle a characteristic set of parameters in the descriptions of an interaction, for example, those of a resonant amplitude for an interaction of *A* and *B* in a definite quantum state, which characterize in conventional terms the particle *C*. We call such interaction parameter sets, "interaction slots."

The abstraction of the free particle, the particle not in interaction, is intimately connected with the presuppositions of an absolute space-time. In our sense it is therefore speculative and unnecessary, and where it appears in conventional theories we will suspect (and find) trouble. It is another consequence, perhaps the most important, of the older view. Only if space-time is taken to be an antecedent system of points both independent and more basic than the interactions said to go on "in" it, is the *unequivocal path* defining a particle in the old conception necessary, and a prior condition to be satisfied. Instead of single points of space and time, particles are groups of interaction slots characterizing each kind of interaction. One can then define a particle coming into an interaction either as a slot in that interaction or as a slot in the previous interaction, and these would be translatable into different derived space-time location systems.

We would eliminate single particles as *fundamental* notions.

SECTION II

A host of anomalies can be predicted, found, and understood from this critique. We find them just where we expect them, namely wherever the requirements of single point space and time systems are put ahead of the requirements of interaction descriptions. Frequently the difficulty arises with one of the manifestations of single point systems, namely the single particle as a lone traveler in single point space-time. The view that a single particle traveling alone, and its path, should be definable already implies that single point space-time systems are preeminent, and that interactions must be described within such a system (or within corrections for two such systems). We have shown, on the other hand, that particles can be

considered as interaction slots, as basically not alone, and that therefore a single particle is a partial expression of some actual interaction.

After presenting the following list of anomalies we will return to our main discussion in Sec. III.

Consider first a simple example from quantum theory. A free particle *with definite momentum* (the interaction parameter) must be described by a wave infinite in extent in space. This means there is no greater probability of *finding* the particle here than there, or even at infinity. In practice, “wave packets” or other localizable descriptions are concocted to avoid such difficulties, but the connection between definite momentum and an unlocalizable state is fundamental. In the limit of definite momentum the state becomes nonlocalizable; the theoretician must impose the localization. This is in sharp contrast to an interacting particle. If the electron is bound in a hydrogen atom by its interaction with a proton, which interaction is ongoing and not momentary, actual and not merely artificial, then it has very definite localization properties definable in terms of (and derivative from) energy parameters of the *bound* system. The interaction generates the possibility of meaningful space-time measurements on the system. The space-time parametrization is complicated, the energy (interaction) description a much simpler way of looking at this system. The average spatial extension of a hydrogen atom can be defined; one defines it from the parameters of the electro-magnetic interaction observed (masses, charges, universal constants defining the units) and parameters of the interaction $A-B$, electron-proton, energy E_{AB} and relative angular momentum l_{AB} . The spatial extension of a free particle is not a meaningful question as no actual interval has been generated by any interaction.

The mathematical absurdities and other problems which arise in quantum theory from the assumption of free particles support our view that the free particle is one instance of speculative results imputed from space-time comparison systems and their artificial space-time points. It seems that on-mass-shell (free) single particles have had a special (real) status in our theories only because we have given an unjustifiable role to single free particles in our thinking.

Our analysis predicts trouble spots in an uncanny way, we find them if we continue to look where absolute space-time points and their relativity corrections are imposed. We find another such example in *local fields*, the name given to the mathematical function which defines the probability that particles of given quantum numbers (charge, mass, spin, etc.) will be created or destroyed at given points of space and time. Quantum field theory postulates that at every point of space and time one can define such a probability. As we would have predicted for space-time point definitions, the local field theories do not work! The theory produces only free particle fields. A realistic equation for interacting particle fields has never been solved.

Looking further, we note that these free fields cannot be chosen in certain, perhaps desirable, ways because the relativity postulates restrict the possible choices so much that, for all practical purpose, they determine them completely. The Lorentz transformations are called *point transformations*; and it is their point-for-point character which requires the point-by-point definition of the free fields, and leads to their “local” character, their being defined with reference to space and time.

Once again, then, space-time as viewed in relativity, and the free particle concept, are seen to be part of the same conceptual scheme, and both suspect. Furthermore, Feynman’s interaction rules (for the interaction of electrons with light) which are successful are in a form that can avoid all reference to space-time and work only in terms of interaction variables, as we have defined them. When his solutions are formulated in space-time variables, they become extremely complicated mathematically; and their derivation from field theory is beset by problems.

We would expect further difficulties where relativity forces certain characteristics upon

light, to make up for the needs of two space-time comparison systems, which characteristics then are maintained for light generally. Photons have to be assigned a zero rest mass, to insure their required signalling properties. Thus, any amount of energy, however small, is enough to produce arbitrary quantities of light quanta ($E = mc^2$, where $m = 0$). Other particles, such as the neutrino, also have rest mass = 0, but the difficulty of producing arbitrary numbers of them from arbitrarily small energies does not arise. Why not? Because neutrinos occur only in conjunction with some other particle (possibly an antineutrino), with a finite threshold for production. Thus it is again the supposedly single particle which is making the difficulty. As we emphasize, a particle makes sense only in relation to a partner, i.e., in interaction variables. Only derivatively from such interaction, and in it, can the particle be treated as "one at a time."

Photons were invented to account for the seeming localization of their energy and momentum in experiments where they interact with electrons. In such interactions they are localizable. Extending the localization demands to free particles, free photons, should make anomalies. It does. It is well known that there is no space-time probability (no wave function) for a photon. Thus it is not localizable at all. But, conversely, the experiments with photons and electrons in interaction, just mentioned, can also be accounted for quite accurately without a localized photon.

Furthermore, we note that zero mass, unpaired-type solutions of the free particle equations and point local field theories lead to still another difficulty: the divergence problem (absurd results such as the infinite mass of particles and in general many infinite values for observably finite quantities).

Thus, we find again that insisting on the speculative space-time formalism rather than the priority of interaction leads to unneeded complications and internal contradictions. We found them where we expected them when we pursued these speculative requirements.

Similar arguments can be made briefly for some other well-known difficulties in conventional theory. In field theory, for example, Haag's theorems [5] and related results establish that there is no acceptable correspondence (unitary transformation) between free-particle fields and the interacting-particle fields when we include interaction in the time-evolution of the system. Streater and Wightman find this "awkward" and "very inconvenient" [5, pp. 166–68]. We interpret it as the inadequacy of field theories to describe essential features of interactions by a formalism based on free particles and local fields.

Another theorem within local field theory, the CPT theorem, requires the universality of the CPT (antiparticle-*plus*-space reflection-*plus*-time reversal) symmetry of local interactions, where each field is evaluated at the same space-time point, as a consequence of locality and relativity postulates. In such theories, it is postulated that there is a local point-to-point causality condition, which we would not expect to hold for infinitesimally near points x , y , for interacting fields. Empirically, it may well be that there are systems which cannot be fit to this procrustean bed, e.g., weak interactions in K-meson decays. There one observes a violation of part of the CPT symmetry (CP), but no compensating direct violation of the T-symmetry is known which would restore the supposedly universal CPT.

The spin-statistics theorem, deriving from these same postulates, has also run into a possible exception. It seems to occur precisely in a situation where the possibility of particles existing in free states is problematic: spin and statistics for the quarks [6]. The quark statistics anomaly is currently circumvented by the assumption that free particle quark states are impossible because of the nature of the quark interaction!

What alternative hypotheses and formulations are suggested or supported by the arguments we have presented? In the most widely used alternative to local field theories, the *S*-matrix model, we again find problems of the same sort. No realistic solutions have been given that meet the two main criteria of the theory: maximal analyticity and unitarity. Analyticity here is the analogue of relativistic point transformations, free-particle basis states,

and local causality in the field theories. Unitarity assures the conservation of probability in interactions and does not appear to depend on any of the speculative features we have identified.

In the unitarity equation, interactions connecting initial and final states (i and f) in one process must agree with those connecting each to all possibly other intermediate states. Maximal analyticity limits the set of possible intermediate states, we believe, in such a way that they are not a sufficient set to allow us to satisfy the unitarity equation. The states are limited to those that qualify as “asymptotic scattering states” (in-states and out-states) in which the effects of interaction are neglected asymptotically (compare free-particle states). In quantum electrodynamics, Dirac points out, you cannot neglect interaction in this way; he rejects the whole approach [7]. We suspect that even in strong interactions the effects of dynamics in the interaction region can never be accounted for entirely in terms of the limited set of states conventionally allowed. (This is tantamount to rejecting asymptotic completeness.)

What would be the effect of allowing states that do not correspond to free particles, i.e., ones that appear only in the interaction region but do not have a scattering state as an asymptotic limit? What would such states be like? What kind of theory naturally provides them? Would they help resolve the problems we have identified as being due to the speculative assumptions of relativity and localization that have formerly excluded them?

The states of *interacting systems*, we propose, are to be built up out of the *complete* set of basis states, both those which are analogues of what are now called free particles, and the nonasymptotic states as well. In S -matrix language, the nonasymptotic states are necessary for completeness in the sense of full unitarity; but they give contributions which violate maximal analyticity, and thus introduce violations of *microcausality*, *within* the interaction region. Nonlocal field theories provide states that are nonasymptotic in the S -matrix sense, i.e., do not appear as in-states or out-states.

Very little is known about nonlocal field theories, except that they have been considered physically unacceptable. However, acceptable nonlocal field theories could be constructed if we refuse to be limited by the strictures of relativity, free particles, and the limitation on signal velocity. Many nonlocal field theories, like the form factor theory for weak processes of Pietzschmann [8], suffer from well known limitations, including a macrocausality violation. But nonlocal theories, it appears, do not need to suffer these troubles. Indeed, well-behaved nonlocal theories which have been studied provide one of the most striking agreements with the consequences of the analysis given so far in this paper. In the work of Heisenberg [9], Kirzhnits [10], and very recently, Sudarshan [11], a very striking common feature has emerged from three different attacks on this problem. It appears that all self-consistent nonlocal field theories are of one type: those which require the introduction of states (as the analogues of particles or fields) which would not be admissible as free particles (not ordinary asymptotic states).

These states (shadow states, ghost states) may have complex mass:

$$M_c = M_0 + iM_0.$$

The imaginary mass can correspond to faster-than-light particles (if allowed as free particles, which we would not have). Mechanisms can be provided that appear to confine acausal effects to microscopic regions, especially in indefinite metric nonlocal theories [10, 11, 12, 13]. Analyticity is probably not maintained, but unitarity can be satisfied, though one must reconsider asymptotic completeness as a condition [14], as we would expect. The complete sets of states now add to the scattering states the nonasymptotic ones, and these new states may have complex eigenvalues of energy, rest mass and may have negative norm in the metric space.

In these alternative theories, most of which were in fact developed to deal with divergence problems and other pathologies of local field theories, one can picture analyticity modified in the interaction region by the existence there of new types of states and fields that introduce violations of microcausality. Within regions of order of size of some fundamental length, in processes where interaction energies are high and approaching some cutoff value, the effect of the new states tends to make all points within the region equivalent: there would be no separation of information at one point from that at another in the region, the "points" would be in effectively instantaneous communication.

Such a picture is paradoxical when we fall back on our speculative notions of points, free particles, etc. Ultimately, even the nonlocal theories with their new states only patch up the holes in the usual fabric of theories derived from relativity and localization. If the topology of space-time is to be derived from interaction, interactions must be written down in terms that allow more general topologies. Our arguments suggest that this will not be done so long as interactions are considered to go on in a prior space-time. When we can formulate them in "internal" spaces of their own parameters, we would expect to find that we can derive a space-time whose topology is effectively similar to that suggested by these descriptions of alternative hypotheses to local, relativistic field theories and *S*-matrix theories.

SECTION III

Our examples have shown that there is indeed trouble exactly where the requirements of single point space-time are imposed as superior to the requirements of interaction. In many cases (for instance the nonlocal models), the needed interaction descriptions already exist but are held inadmissible because of the old view. It would thus have important consequences for theory building if, as we propose, interaction were considered basic and space-time location derivative. It would mean that the requirements of the latter could no longer limit the former.

Our analysis has shown that space-time point systems are intercomparison systems. A comparer considers all phenomena marked off on all other phenomena (each is thus assumed to be indefinitely divisible—hence points), and the total system of these intervals is the space-time point system.

We showed that such comparison intervals are artificial interactions. Space and time parameters are derivable from interactions. They can be derived from actual interactions. Or they can be derived from the artificial interactions of the assumed interval system of all compared to all. The comparer pretends that for each motion he has taken all others and marked them off on it, and hence all its points have been generated. But these points are a purely speculative set, the comparer has not really compared all phenomena and even the few he has compared have not actually interacted. By marking one motion off on another, the comparer does not make actual interaction between them, nor, unless he freshly measures, is there interaction between himself and them.

Why should this purely speculative set of artificial would-be interaction intervals and their points be considered a system of primary reality lasting across interactions, and to which all interactions must consistently conform?

Our first conclusion, therefore, is that where a conflict arises, the space-time-particle description generated by actual interaction ought to take precedence over the nonactual interval system of comparers, as well as over the requirements of harmonizing more than one such comparer.

Therefore, where it is currently desirable to employ descriptions of interactions that violate the requirements of point-systems and free particles, we have proposed lifting these restrictions.

Our second, more strident conclusion is that single points and single particles are an

impossibility. They result from first setting up comparison systems, then reversing things and making the terminal points of the comparison intervals basic as if they had been antecedent and independent. The single particle traveling freely has to be recognized as hypothesizing the single point and path of points.

“This” particle is identifiable as different from others of the same sort only in and by some interaction. The free particle is defined by the nonactual interaction of antecedent space and time points (it is the one at a given space and time point).

Thus, the absolutely existing “this particle” is as nonactual as the points which identify it. Only actual interaction can identify a particle. Therefore, only interacting particles are possible; and a single particle is a partial description of an interaction, an interaction slot.

Thirdly, we conclude that actual interaction can alter the system of space–time points. We saw that even in classical physics momentum could be described as a system of would-be interactions from which a particle could have come and into which it could go. Such systems of would-be interactions are only again another type of nonactual interactions similar to those of the comparers. An actual interaction changes a particle’s momentum and thereby changes the whole system of past and future would-be interactions because it changes the velocity and direction. Therefore, it is clear that an actual interaction is not simply one of those many would-be interactions, the one that occurred. To so view it is again to make the system of would-be interactions prior and more basic than actual interactions. We would reverse this order and allow an actual interaction to generate a space–time system. This view, while alien to most of current thinking in physics, is at the heart of gravitational theories, in which the properties of space–time (e.g., the metric) are derived from interactions by way of the energy tensor.

It must be kept in view that parameters like frequency, wavelength, momentum, and velocity, involve space and time but are determinable from interaction. Thus, interactions can generate space and time but have not been thought of as generative in this way because, instead, they were thought of as having to go on in, and conform to, antecedent space and time.

If there were no difference between would-be interactions and actual ones, the actual interaction would simply be one of those already included in the system of possible interactions (which a momentum states) for a particle. When it actually happened it would leave the basic system of possible interactions undisturbed, that is to say the changes due to the interaction would be located within that system and would change details within it, but not the system.

The space–time derived from the interaction is different from that before the interaction, in which it was only a would-be interaction among others.

At low energies, the overarching system of would-be interactions might give approximately correct results. But high energies translate kinematically into very small regions; and, thus, very small deviations can involve very high energy values.

Relativity would be viewed as having taken a first step in recognizing that space–time point systems are a function of a comparer. The second step would be to recognize that actual interactions are superior to would-be interactions (such as comparisons and places and times of possible interactions).

Localization (point locality) is really the principle of the “conservation” of space–time point systems, a conservation law nature may not respect!

This analysis also indirectly supports the philosophical model from which it arose [1]. Since the difficulties do appear just where the analysis would lead one to expect them, some credence is given to the philosophical model from which the analysis stems. The model is one of *process* and takes its rise from a conception of knowledge as “explication,” rather than as a copy of reality. In explication, “retroactive time” is the rule rather than an anomaly. One always asserts now what earlier phenomena “were.” When this is projected on linear point time, it

gives the impression of time doubling back on itself, as it would certainly seem to do if an interaction were described as occurring in an independent, prior space-time which can only be derived by working back from what is really prior interaction itself.

REFERENCES

1. E. Gendlin, *Experiencing and the Creation of Meaning*, Free Press, New York (1962); Revised Edition (1970).
2. A. Einstein, *Annalen der Physik* **17**, 891 (1905).
3. H. Weyl, *Sitzungsberichte der preussischen Akad. d. Wissenschaften*, p. 465 (1918); *Phys. Zeits.* **22**, 473 (1921); see also A. S. Eddington, *Mathematical Theory of Relativity*, p. 200, Cambridge University Press, New York (1960).
4. J. Schwinger, *Particles, Sources, and Fields*, pp. 24, 34–38, Addison-Wesley, Reading, MA (1970).
5. R. Haag, Kgl. Danske Videnskabsk. Selskab, *Nat. Fys. Medd.* **29**, 12 (1955); R. F. Streater and A. S. Wightman, *PCT, Spin-Statistics, and All That*, Benjamin, New York (1964).
6. R. H. Dalitz, *High Energy Physics*, Gordon and Breach, New York (1965). The results of Mitra and Majumdar [*Phys. Rev.* **150**, 1194 (1966)] show that Fermi statistics for quarks leads to charge distributions within the proton that strongly disagree with experiment.
7. P. A. M. Dirac, *Lectures on Quantum Field Theory*, Harper and Row (1962).
8. H. Peitschmann, Universität Wien reprint (1970).
9. W. Heisenberg, *Rev. Mod. Phys.* **29**, 269 (1957).
10. D. A. Kirzhnits, *Soviet Physics Uspekhi* **9**, 692 (1967).
11. E. C. G. Sudarshan, *Proceedings of the 14th Solvay Conference*, pp. 98–115, Interscience, London (1968).
12. T. D. Lee and G. C. Wick, *Nuclear Physics B* **9**, 209 (This discussion of negative metric theories assumes a unitary S -matrix).
13. R. Oehme, in *Quanta*, P. G. O. Freund *et al.*, eds., pp. 309–338, University of Chicago Press (1970).
14. R. Marnelius, *Phys. Rev. D* **10**, 3411–3430 (1974).